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O.M. Braun, N. Miyashita, H. Fujii, B.N.J. Persson

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On the load dependence of friction: role of the long-range elastic coupling

O.M. Braun[a,b] N. Miyashita[c] H. Fujii[c] B.N.J. Persson[b,d] *

[a] *Institute of Physics, National Academy of Sciences of Ukraine, 03028 Kiev, Ukraine*

[b] *PGI, FZ-Jülich, 52425 Jülich, Germany, EU*

[c] *The Yokohama Rubber Company, 2-1 Oiwake, Hiratsuka, Kanagawa 254-8601, Japan*

[d] *www.MultiscaleConsulting.com*

Abstract

When an elastic block is squeezed in contact with a substrate the contact will in general consist of many asperity contact regions. During sliding the long-range elastic coupling between the contact regions have a big influence on the sliding dynamics: when the loading force increases the density of contact regions increases, which affects the lateral coupling between the contact region, and introduces a dependence of the friction force on the loading force. Here we present a full three-dimensional model study of the role of the elastic coupling on the friction force. The theory is applied to rubber friction, but the mechanism for the dependence of the friction coefficient on the load is relevant for non-rubber materials as well.

1 Introduction

The Amontons friction law states that the friction force $F_{\rm f} = \mu F_{\rm N}$ is proportional to the normal force or load $F_{\rm N}$, and is found to hold remarkable well in many practical applications [1–3]. For elastic solids with nominally flat but randomly rough surfaces, contact mechanics theories and numerical simulations show that the contact area A is proportional to the nominal contact pressure $p_0 = F_{\rm N}/A_0$, where A_0 is the nominal contact area [4–12]. If it is assumed that a characteristic frictional shear stress $\tau_{\rm f}$ acts in the area of real contact, then the friction coefficient $\mu = \tau_{\rm f} A/(p_0 A_0)$ will be independent of the

* Corresponding Author.
Email address: b.persson@fz-juelich.de (B.N.J. Persson[b,d]).